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AN ELECTRICALLY OPERATED VALVE FOR CONTROLLING FLOW OF HYDRAULIC FLUID

The present invention relates to an electrically operated valve for controlling flow of hydraulic fluid.

The present invention will be discussed with particular reference to the use of valves for controlling flow of hydraulic fluid to actuators attached to engine valves of an internal combustion engine. It has often been suggested in the past that in an internal combustion engine a mechanical cam shaft could be replaced by a series of hydraulic actuators which would open and close the engine valve. The hydraulic actuators are controlled by controlling the flow of hydraulic fluid to them. Various different arrangements of valves have been proposed for the control of hydraulic fluid. However, there is still a need for a simple and cost-effective valve arrangement and this issue is addressed by the present invention.

The present invention provides an electrically operated valve for controlling flow of hydraulic fluid comprising:

a valve housing;

a spool slidable in a spool chamber in the valve housing;

a first fluid conduit extending through the valve housing for connecting the spool chamber with a source of pressurised fluid;

a second fluid conduit extending through the valve housing for connecting the spool chamber with a reservoir of fluid; and

a third fluid conduit in communication with the spool chamber which delivers fluid to or receives fluid from apparatus which uses the hydraulic fluid flow controlled by the valve; wherein:

the spool is biassed to a rest position by a pair of opposed springs;

the spool in the rest position thereof closes off the first
and second fluid conduits from the spool chamber and thereby prevents flow of fluid to and from the third fluid conduit;

the valve has a first electric coil associated with a first end of the spool and which can be activated to displace the spool from the rest position thereof to open the first fluid conduit to the spool chamber, whilst keeping closed the second fluid conduit, and thereby to allow pressurised fluid to flow from the first fluid conduit to the third fluid conduit; and

the valve has a second electric coil associated with a second end of the spool and which can be activated to displace the spool from the rest position thereof to open the second fluid conduit to the spool chamber, whilst keeping closed the first fluid conduit, and thereby to allow fluid to flow from the third fluid conduit to the second fluid conduit.

A preferred embodiment of the present invention will now be described with reference to the accompanying drawings in which:-

Figure 1 is a schematic illustration of an electrically operated valve for controlling flow of hydraulic fluid

according to a preferred embodiment of the present invention;

Figure 2 is a schematic illustration of how the valve of Figure 1 could be used in an internal combustion engine.

Turning first to Figure 1 there can be seen an electrically operated valve 10 controlling the flow of hydraulic fluid therethrough. The valve 10 comprises a valve housing 11 having slidable therein a spool 12, the spool being slidable in a spool chamber 13 provided in the valve housing 11.

A first fluid conduit 14 extends through the valve housing 11 and connects the spool chamber 13 with a source of pressure.

A second fluid conduit 15 extends through the valve housing 11 and connects the spool chamber 13 with a return line for returning hydraulic fluid to a reservoir.

A third fluid conduit 16 extends through the valve housing 11 and connects the valve 10 to whatever apparatus receives the flow of hydraulic fluid controlled by the valve 10.

In Figure 1 there can be seen two opposed springs 17 and 18 which together act to centre a spool 12. When the spool 12 is centred both springs will still be compressed and will still each apply a force on the spool 12, but the forces applied by the two springs 17 and 18 will be equal and opposite.

Two electric coils 19 and 20 surround the ends of the spool 12. Surrounding each end of the spool 12 there is provided an armature 21 and 22.

The spool 12 is surrounded by a sleeve 23. This sleeve 23 has two annular end surfaces 24 and 25. The annular end surface 24 faces an annular end surface 26 of the armature 21. The annular surface 25 faces an annular surface 27 of the armature 22.

When the electric coil 20 is actuated then the magnetic circuit acts to draw the armature 22 into engagement with the annular surface 25 of the sleeve 23. Thus, the spool valve is moved to the right of its position shown in Figure 1, against the biassing force of the spring 18.

When the electric coil 19 is activated then the magnetic field generated by the coil acts to draw the armature 21 towards the annular surface of the sleeve 23 and thereby move the spool 12 to the left of its position in Figure 1, against the biassing force of the spring 17.

With the spool 12 positioned as shown in Figure 1 the pressure line 14 and the return line 15 are both sealed off from the spool chamber 13 and therefore no hydraulic fluid can flow to or from the fluid conduit 16.

When the spool 12 is moved to the right of its position in Figure 1 then the fluid conduit 16 is connected via the spool chamber 13 with the return line 15 and therefore fluid can flow from the line 16 through the spool chamber 13 to

the fluid conduit 15 and thereby to a reservoir of hydraulic fluid.

When the spool 12 is moved to the left of its position in Figure 1 then the conduit 14 is opened to the spool chamber 13 whilst the conduit 15 remains sealed. Thus, pressurised fluid can flow through the conduit 14 to the conduit 16 via the spool chamber 13.

The fluid conduit 16 is permanently open to the spool chamber 13.

In Figure 1 there can be seen a null adjust mechanism 28. This comprises an externally threaded rotatable screw 50 provided in a threaded bore 51 in the valve housing 11. A hexagonal socket 52 is provided at the tip of the screw 50 and can be engaged and rotated by an Allen key. An eccentric cam 53 extends downwardly from the screw 50 and acts on a reaction

surface provided on the sleeve 23. On rotating the cam 53 it is possible to slide the sleeve 23 within the valve housing 11. This can be done to ensure that when the two electric coils 19, 20 are deactivated and the spool 12 brought to a central position by the two springs 17 and 18, then the ports in the sleeve 23 via which the pressure line 14 and the return line 15 open onto the spool chamber 13 are both closed off by the spool 12.

By having a high pre-load applied on the spool 12 in its

resting position by both the spring 17 and the spring 18, with the forces applied by the springs cancelled out by each other, it is possible to set a low spring rate and to determine how much force must be applied to move the spool valve 12 from its centralised position. This feature allows the valve to be used easily as a metering valve, because the current flowing through each of the electrical coils 20 or 21 can be adjusted to give a variable displacement of the valve spool 12, a variable degree of opening of the ports in the sleeve 23 and therefore a variable rate of flow through the valve 10. However, if wished, the valve 10 could operate as a switching valve, moving only between extreme positions by applying high value square-wave signals to the coils 19 and 20.

Moving now to Figure 2, the valve 10 can be seen represented schematically. The pressure line 14 is shown connected to a pump 30 and the return line 15 is shown connected to a reservoir 31. The line 16 is shown connected to an actuator 32. The actuator 32 comprises a piston 33 movable in a cylinder defined by a sleeve 34. Piston 33 and the sleeve 34 define together a variable volume chamber 35 which receives hydraulic fluid via the line 16.

A position sensor 36 is built into the sleeve 34 and provides a feed back signal to an electronic controller 37. The electronic controller 37 uses the feedback signal along with other received parameters to provide a control signal which is relayed to the valve 10. As explained before, the control signal will be used to apply a current to one of the two coils 20 and 19.

When the actuator 32 is connected to the pump 30 via the valve 10 then the piston 33 is caused to move downwardly and to open an engine valve 40 of an internal combustion engine, (e.g. an inlet or an exhaust valve).

When the actuator 32 is connected to the reservoir 31 via the valve 10 then a valve spring 41 acting on the engine valve 40 can force the piston 33 to reduce in volume the chamber defined between piston 33 and sleeve 34, with the dispelled fluid being relayed via the valve 10 to the reservoir 31.

The electronic controller 37 is part of a closed-loop feedback system which controls the position of the engine valve 40. The electronic controller 37 will send a demand signal to the valve 10 in the expectation that this will result in a position (and perhaps a rate of change of position) of the piston 33 and therefore the engine valve 40. The displacement transducer 36 will provide a signal which can be used to generate an error signal so that the electronic controller 37 can adjust the control signal it sends to the valve 10.

The use of feedback signal is important since the provision of a closed loop feedback system can provide for adaptive control, with the electronic controller making adjustments during the life of an engine to account for wear of components in the engine.

Whilst above the armatures 21, 22 are movable within the electric coils 19, 20 they could be formed as radially

extending plates each with a surface facing an opposed end face of a coil 19, 20 (either an inboard or an outboard end face of a coil). The housing 11 would be provided with suitable chambers adjacent the coils 19, 20 in which the radially extending armatures could move. Whilst the springs 17, 18 are shown within bores in the spool 17, they could be mounted externally of the spool (perhaps in the spool chamber) if more conveniently.

The rate of opening of the valve 40 and the rate of closing of the valve 40 can be controlled by controlling the rate of flow of fluid through the valve 10.